THE

Indian Tea Association

SCIENTIFIC DEPARTMENT

QUARTERLY JOURNAL

PART III

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ESSENTIAL GARDEN WORKS AND POSSIBLE ECONOMIES.

BY

H. R. COOPER.

In the last issue of this Journal it was assumed that the garden operation of pre-eminent importance is plucking, and that other operations, aimed towards growth of more crop, must take places of subsidiary importance to the harvesting of the crop already there, at such a stage in its growth that the produce shall be of maximum quality.

It was agreed, however, that if the suggestions for plucking for quality were followed, then on many (if not most) gardens in North East India, not only would smaller crops per acre be produced (which may be desirable), but more labour per lb. of tea would be required, with a consequent increase in cost of production, which might go far to counterbalance the benefit from increased prices.

It is very necessary therefore to do all that is possible that crop should be saved, whenever the cost of saving is little, and the cost of operations other than plucking should be restricted to the minimum likely to maintain crop at a remunerative level.

What that remunerative level is must be decided by those responsible for each particular garden. It is quite clear that there is such a level for each particular set of circumstances. As crop per acre increases at least up to a certain maximum so are costs per lb. of tea reduced.

The concentration on a smaller area saves supervision and transport costs.

Tea covering the ground requires less cultivation than widely-spaced bushes. The effects of factors leading to soil deterioration (loss of organic matter and nitrogen by oxidation and washing out, the puddling effect of heavy rain, and invasion by types of jungle which are the most serious pests of tea) are reduced;

while the cover from good bushes, the presence of vigorous roots in the soil, together with the addition to the soil of leaf-fall and prunings in quantity, produce soil-improving effects approximating to those which produced the well-known excellencies of virgin jungle soil. Relatively small additions of artificial manure per lb. of tea, will maintain remunerative yields from such tea on normal soils.

On the better tea, pruning costs per acre should be somewhat increased, but pruning costs per lb. of tea are greatly reduced.

The weight of leaf gathered per cooly per day is observed to increase with increasing yield per acre up to certain point. Tea yielding extremely well is so close-packed, and its outer branches are so stout and stiff, that it becomes difficult for the pluckers to push between the bushes, while the centres of the bushes become difficult to reach. Very high yielding bushes may be more liable to disease. It is commonly the case, also, that very good-yielding bushes are kept too high for convenient plucking. Such very vigorous bushes also require plucking at closer intervals than normal bushes, or the quickly grown shoots are over-ready.

There appears to be a point, therefore below which costs of production increase progressively, but above it excessive yield gives little further economy in production.

The ideal would appear to be tea covering the ground, but with its outside branches not too stiff and strong, and pluckable at about 7 days interval. About 9 to 11 mds. tea per acre is suggested as roughly the minimum yield per acre to aim at for production of good tea at low cost in the plains of North East India. Amply laboured gardens can work much higher yields with consequently improved profits per acre, but probably with little reduction in cost per lb.

The effects of the factors which have just been discussed are now being very strongly impressed upon practical men by results in practice. Areas of very low yield cannot be worked at costs sufficiently low to make ends meet at present prices for tea, unless teas of outstanding quality are produced.

It would appear therefore that such areas must be worked at a loss in the hope of better times in the future, or abandoned, or brought up to standard : while areas now good must not be allowed to deteriorate too far. It is in these connections that the, at present, unpopular subject of manuring must be discussed in addition to pruning and cultivation which cannot be avoided.

This, of course, is no place for complete treatises on these big subjects. Remarks must be very brief and confined to changes proposed in common practice in concordance with recent findings, or to meet the present situation.

Pruning.

Cutting Back. It is strongly urged that, at the present time, any cutting back should be confined to such reduction of height as is necessary to increase ease and accuracy of plucking. The heavier the cut, the heavier and the longer continued is the loss of crop, and (more important) of quality. Collar pruning, or really heavy pruning is estimated to reduce crop and quality for at least six years.

A clear distinction should be made between pruning for height reduction, and heavy pruning for renovation. The latter, unless very carefully and expensively performed, is more likely to start deterioration than improvement and it is suggested that real renovation, involving expensive pruning over several years, greatly increased cultivation and manuring costs, accompanied by loss of crop and quality for years, should be looked upon as similar, financially, to replanting; which indeed it commonly involves to a large extent, since a large percentage of deaths commonly follows really heavy pruning. A cut at between 20″ to 24″, on the other hand, produces all the height reduction necessary. It involves no increase in vacancies, and since the cuts will be on relatively thin wood, the die-back (which is bound to occur) involves less cutting out of heavy wood, and leaves wounds relatively easily healed. The good growth (not less than 12″ in the first year) which must follow for at least two years, involves a much smaller loss of crop and quality for a much short-

er time. Since the cover is not greatly reduced for long, cultivation costs are not greatly increased, nor is there much fear of introduction of undesirable weeds, as there is after really heavy pruning.

The opportunity of seeing the frames should of course be taken advantage of, to remove diseased or damaged branches, flush with a healthy branch, or to just above a shoot or bud. Not much should be spent on this work in the year of heavy cutting: in the following year dead wood can be cut out flush with the new shoots which have arisen to leave a permanent job. If it is decided that this removal of dead wood cannot be afforded, it is suggested that it would be much better from all points of view to postpone cutting back, till it can be done in a manner which will not start deterioration of the bushes.

Light Pruning. This applies both to annual pruning and to tea which has been unpruned. The disadvantages and possible advantages of unpruned tea were mentioned under "Plucking" in the previous issue of this Journal.

One of the most important observations with regard to field work, within recent years, is that the time of pruning has a much greater influence on yield in the following season than has commonly been appreciated. On the particular tea used for this measurement at Borbhetta average yields in 1930 were:—

Pruned Dec. 2nd.	...	11.32 mds. tea per acre.
,, Jan. 11th.	...	9.85 ,, ,, ,,
,, Feb. 20th.	...	8.47 ,, ,, ,,

and similar results were obtained in 1929.

Roughly this comes to a loss of 1 md. tea per acre for each month late in pruning.

The later pruned tea naturally comes into plucking later. That of course was always well known; but the natural consequences that the later pruned tea is not yielding fully in June when there is plenty of labour to pluck the good tea of that season, and that the later pruned tea at that time is yielding mixed first

and second flush teas of inferior quality, deserve wider appreciation. It had, also, not been appreciated that the later pruned tea not only comes later into bearing, but also yields less throughout the season—even in October. It costs a little more, but not much, to prune early instead of late, and it is suggested that the extra crop obtainable for so little should be taken advantage of.

The practical suggestions made here for consideration are :—

(1) Any tea which has been left unplucked (and so strengthened) for the whole or part of the season should be pruned as early as labour is available for the purpose—perhaps in October, and certainly in November.

If some tea has to be left unplucked it would be sound to arrange that all tea which is in poor condition, and is intended to be cut-back, should be among the areas so left unplucked, and ear-marked for early pruning; but areas to be top-pruned, also, should be pruned not later than November if they have been left unplucked.

(2) Although there are no exact experiments to prove this point for all cases, it appears pretty certain that it is the date of first pruning which makes the big difference, and that the date of cleaning out makes little difference. An indication in this direction is afforded by the fact that, at Borbhetta, the loss of crop from late pruning was almost as great from bushes not cleaned out as from bushes cleaned out. The second suggestion, therefore, is that in order to finish pruning early, the whole garden should first be cut across, without any cleaning out.

The cuts should be clean and should leave the amount of wood desired, so that no repair work entailing a second cut on the same wood is necessitated at the second pruning sometime later. (Wood pruned again after drying will not bleed, will probably not heal, and will probably die back for some distance). At Bor-

bhetta this year, this first pruning started on December 1st., and was finished on January 3rd., although this is a time when the attendance of the village labour is reduced by the rice harvest. Pruning and cleaning out at the same time had in previous years not been finished till well into March.

At Borbhetta to get good work it was found necessary to make each cut in the ordinary way, "slashing" being permitted only to finish off weaker outside branches. On some gardens, however, very good work has been seen, done by "slashing" with big sharp knives by well practised labour. It is a great advantage of this method of pruning that flat surfaces to the bushes are easily obtained. This makes tipping a much easier matter, and avoids loss of crop while waiting for shoots from low-cut wood to reach the plucking surface. Its disadvantages are that there is a tendency to leave rather longer wood than is desired, and that the total cost of cutting across, and cleaning out later, is rather more than that of combining the two in one operation.

It is suggested that *all* the labour capable of using knives should be concentrated on this work (which is looked upon as the most important at this time), from about December 1st.

Plucking should continue only where there is sufficient leaf to make the running of the factory remunerative; and it must be remembered that any gains of crop at this low-yielding time, which are made at the expense of early pruning, will in most seasons be much more than counterbalanced by losses in the following June and throughout the following season.

Cultivation should be carried on only by people incapable of pruning.

Cleaning-out. Should be pushed on as rapidly as possible after the cutting across is finished. In this matter district customs vary so widely that it is necessary to give some account of our opinion of the essentials of the subject.

Where cleaning-out is most neglected, there rotting frames and general deterioration are most in evidence, and cutting back is more frequently thought to be necessary. An accumulation

of *banjhi*, twiggy growth also reduces yield, and quality. Excessive removal of yielding shoots in any district must reduce yield, vigour, and quality.

We suggest that, when a bush is cleaned out, all *banjhi* twigs, all thin shoots which have been plucked only twice, all dead branches (big or small), and all moribund branches producing only weak growth should be removed cleanly. Shoots which have yielded in the previous season will probably yield again and should be left. Bushes so treated will remain in good condition (so long as food supply is adequate), and will rarely need cutting back, except for height reduction which need lead to little loss.

Cleaning out has been found at Borbhetta not to be necessary every year. Where ample labour is available, and there is no other work for it, it is advisable as a precaution : but where labour is short or where it is essential to keep down costs, it is suggested that the aim might be to clean out thoroughly (removing dead and moribund wood) at least a quarter of the garden, and to remove *banjhi* twiggy growth only from the remainder of one half of the garden : leaving one half of the garden merely cut across with no further attention. Where only a little cleaning out can be afforded it should be of the more thorough type suggested.

Areas left not cleaned out will look yellow and untidy in the spring, and will be worse attacked by red spider than the cleaned out tea. Tipping also is more difficult, since one gets a much less even rate of growth from bushes not cleaned out. Yet at Borbhetta, in spite of this bad appearance, tea not cleaned out for two years yielded almost as well as the corresponding cleaned out plots : though in the third year of neglect of cleaning out, there is a marked decrease in crop and a marked increase in disease including thread blight. On the other hand, the bushes not cleaned are the wider and cover the ground better. From the cleaned out bushes outside branches have been removed which were thought to be useless, but have been proved to be capable of development, by the behaviour of the corresponding bushes from which nothing had been removed.

When it is necessary to choose areas for cleaning out, the older and higher bushes should be chosen. Younger bushes, and bushes more recently cut back (if cleaned out in the year following cutting back) will suffer less from neglect.

In most gardens in Assam, the expenditure on cleaning out may be reduced safely. When it is done, attention should be paid to removal of what is bad, and to the leaving of what is good, rather than aiming at a bush which *looks* very clean, but is still carrying bad wood and is too empty, and without sides. In most other districts more attention to cleaning out will save crop and quality, and more particularly the necessity for "renovation".

Cultivation.

While it is not suggested that deep stirring of the soil has never any value: it appears quite clear that, except in the relatively rare cases of soils which are "panned", depth of cultivation is of little importance compared to jungle suppression.

At Borbhetta plots not deep hoed maintained for four years the same crop as plots deep hoed annually: in the succeeding five years the continued neglect of the deep hoe has been followed by progressive, but very small, losses in crop. The withdrawal of the same amount of labour from surface cultivation in the growing season (reduction from six light hoes to four) has produced large losses of crop annually. That it is the presence of the jungle, and not the soil-stirring by the light hoe, which has been the effective factor, is made clear by the following examples. Crops are no better with 11 light hoes than with 6 light hoes, presumably because the 6 light hoes in this good tea keep the land clean. Crops also are equally good when the soil is not stirred at all, but jungle suppressed merely by scraping the surface. On the other hand, where the soil is well stirred by digging with English forks, three times a year, but jungle allowed to grow between these rounds of good cultivation, there the tea can only be described as miserable.

Where the supposed benefits of deep cultivation are extended to the subsoil by an annual hoe to 18″ deep (performed with ex-

treme care so that no roots are cut) no benefit at all has been observed in any year, but whenever (as in 1928) serious drought follows, the very deep hoed plots suffer badly, presumably by the disturbance of roots, which are left in loose dry soil, with no power of obtaining water.

We may take it then, that depth of cultivation and the stirring of the soil are, in normal tea soils of North East India, factors of minor importance; and that the maintenance of reasonably clean soil is of primary importance. Steep slopes need special consideration but that is too big a subject to be dealt with here; except to remark that if cover crops are necessary, they should be selected to be of as harmless a nature as possible, not chance-produced weeds, and certainly not grass of any kind.

Any other plant growing among tea does damage. Even legumes, while growing, reduce crop, although the loss is small and more than made up by the gain of nitrogen to the soil when the leaves have rotted down.

The worst offenders are the coarse grasses growing from underground running stems, generally referred to as thatch (*kher, ulu, sirru, kasi*). These are major pests of tea. On plots at Borbhetta, deep hoed annually in the cold weather, but afterwards sickled only, the tea yields half as much as similar plots cultivated, but is still quite good (it is lightly manured) in patches wherever the thatch has not yet invaded. Wherever the thatch is thick the bushes yield practically nothing, and are dying out. But even low-growing shallow-rooted grasses reduce crop and vigour very considerably.

If the opinions here indicated are believed in, there is room for economy in cultivation.

The old very deep hoe, which was responsible for large additional expenditure on recruiting, is falling out of general use, and it will not be missed, except in rare instances where the soil is panned: but even the ordinary annual deep-hoe, could be cut down generally, without any loss, to once in four years, or to be on the perfectly safe side for heavier soils, say, once in three

years, as a start. Here it must be pointed out, that apart from deep-stirring, the ordinary deep hoe has a great value in jungle suppression. The first cut leaves a shallow trench (7″ or 8″ deep) across the land, into this weeds are scraped being very effectively collar-pruned and damaged : the next clod is turned upside down over the weeds. This is very effective jungle suppression, (particularly if dry weather follows) and this "cheel-and-bury" hoe should continue on weedy sections, if there is labour to spare for it.

It has, however, very little value on soil already clean of weeds, or on soil where the following light cultivation will be efficient, as quite a small number of good light hoes will be, where the tea (particularly if assisted by shade trees) affords reasonable cover.

The light hoe similarly has little or no value on land free of weeds; but if there are weeds of any kind, then it will do good to destroy them. While we think economies may be effected, if it is appreciated that clean land needs (except in rare circumstances) no cultivation; yet we do not call land clean in the cold weather, when one sees nearly bare soil, with spikes of thatch sticking through the surface, nor can land be called clean if it has a covering even of low-growing shallow-rooted grass, though this does less harm, particularly in wet weather. It should be clearly understood also that this Department has never given any opinion in favour of what is called in Assam a "Kachari hoe", which is probably one degree worse than the "Bengali hoe" of the Surma Valley. Both these classes of casual labour, no doubt, *can* do good work, but "cultivation" which merely knocks down the highest jungle, so that it is not seen from the road, and covers much of the remainder with a layer of soil, leaving most of the roots undisturbed, is useful only in that it assists the pluckers for a short time. It does very little indeed to confer the benefits of clean soil which make so much difference to the yield and to the health of the tea bushes. A good light hoe should slice off a sod and turn it over, turning the next sod on to the clean soil so left. This type of cultivation can be as shallow as the cooly likes, in

fact the shallower the better for most types of jungle because root is better separated from stem and more damage done; but the common modern practice of using one sod to cover the next untouched piece of ground is one to be discouraged gradually till the cooly returns to his old good habits.

The efficiency of cultivation, under the conditions of the plains of North East India, should be judged by the degree of freedom of the soil from weeds, and not by the number of hoes which have been given. If tea provides cover so good that no weeds grow, then the cultivation should be judged as 100% efficient although no cultivation whatever has been done. Under such conditions there need be no fear that tilth will suffer. It will not be possible to puddle the surface formed of rotten leaves and prunings; and the subsoil being never interfered with by the implements of man, but filled with vigorous roots, and subject to seasonal wetting and drying, will assume the perfect tilth of virgin jungle soil. On very many gardens there is at least one patch of such tea, which never is cultivated. Some receive, on paper, a certain number of hoes; but as there is no room to swing a hoe, they receive actually nothing but a little scratching. In some cases this is appreciated, and no cultivation is even paid for. Such soils, if unmanured, will fall off in yield very slowly indeed: and if they carry shade trees, these usually will be so efficient, that high yields may be maintained with no other application of manure at all. Such tea yields at least 16 mds., per acre, perhaps over twenty, and represents an exceptional, ideal case.

The average yield in Assam is about 8 mds.: in other districts less. Average tea requires cultivation, or it will be starved by the presence of the jungle, and will deteriorate rapidly.

Economics in cultivation can be effected without loss, only by adjusting it to the requirements of the situation.

If weeds are present, they should be attacked whenever there is labour available for the purpose. If absent, nothing should be spent on stirring the soil, except under special conditions. During July and August it is generally the case that all the labour

available is required for plucking. During that time cultivation must be a secondary consideration : and it is advised that cultivation during rush times should be afforded only when labour can be spared without interfering with the efficiency of plucking : or when jungle must be got out of the way to allow plucking to proceed without undue difficulty and delay. At this time, if sickling covers ground more rapidly than hoeing, it will as well effect this object temporarily, but not for so long a time, while it will do little to bring a flush, if that is desired. The presence of enough jungle to reduce the rate of growth of the tea, without hindering plucking, sometimes may be an advantage, since it will better enable bushes to be kept within control by a short labour force.

Through the growing season, if it is found cheaper to suppress jungle by cheeling, (scraping) rather than hoeing, then cheeling should be adopted.

As soon as labour is in more plentiful supply weedy sections should be cleaned up.

On many gardens cultivation is neglected in October and November, sometimes with the idea of saving expenditure, sometimes with the idea that jungle can now wait for the deep hoe, with which it is often considered desirable to have some jungle to turn in. This we consider a serious mistake. During the drier weather, cultivation has a much greater jungle-killing value, than at a time when weeds are merely transplanted; and the autumnal crop will be increased if the soil is clean.

Autumn cultivation also has a great value as a preparation for the cold weather. Even in the most favourable of our climates, tea suffers to some extent from the spring drought, while in the more extreme districts, this is the most serious handicap to profitable tea growing. The maintenance of clean soil is a most valuable means of reducing damage from drought. As already explained, December is looked upon as the month for pruning. Every effort should be made to have a clean garden by the end of November, and we consider it very much better to cover the necessary ground with good light hoeing quickly, rather than to

put in a beautiful deep hoe over a small area, while leaving jungle over large areas until late in March, as has often been observed to be done even on relatively well laboured gardens. If there is sufficient labour for it, the thoroughness of the "cheel-and-bury" hoe would be preferred; but early suppression of the jungle should be the first consideration, and light hoeing, if thorough, attains this object.

Some deep hoeing—say a quarter of the garden—should be aimed at, but not at the cost of leaving a garden under jungle.

This deep hoe should be put in not later than January, preferably after the first prune, so as to turn under the prunings. At this time, also, the soil is not yet so dry that any harm need be feared from deeper stirring, (to not more than about 8 inches, and not too close to the collars).

During February light hoeing should continue wherever there is jungle to be killed. If labour is very abundant it will do some good to hoe even a clean soil if it has become consolidated; to leave a light mulch of dry soil over the surface, to conserve moisture in the soil below it. Hoeing should never be abandoned only because the soil is dry. That idea is founded on the misconception that, to be efficient, cultivation must be deep. When the soil is dry, hoeing as a means of killing jungle is most efficient, even if only an inch deep, while the leaving of the mulch is also of advantage.

March is the month when manuring should be done, by this time soil should be clean and light hoeing may be done at double the usual task, if merely for the purpose of covering manures. If no manuring is to be done, hoeing might still carry on at double the usual task, the labour being instructed to hoe only where there is jungle. From April to June jungle is growing fast, and the hoe should go round as fast as available labour allows, with the object of getting a clean garden before the rush season commencing about July 1st.

For average tea in the plains, about six hoes annually, well distributed and thoroughly performed, will yield a full crop: but no standard should be laid down. On some sections none may be

necessary, but nine hoes in the year may leave jungle sufficient to reduce crop seriously, if nearly all of them are given between March and June as has sometimes been done.

A round of forking is also generally necessary. Its main object is to remove jungle from around collars of the bushes. It is not only unnecessary but undesirable that deep holes should be dug around the bushes; but the soil should be broken up, to expose chrysalids, which should be collected if caterpillar pests have been active in the previous season.

CATERPILLAR PESTS OF THE TEA PLANT, AND OF GREEN MANURE PLANTS AND SHADE TREES IN USE ON TEA ESTATES.

BY

E. A. ANDREWS.

Part II.

The Looper Caterpillar.

(Biston suppressaria—Guen.)

Included amongst the many groups of caterpillars is one which is characterised by the absence of the legs generally found on the third, fourth and fifth abdominal segments, there being only one pair, on the sixth abdominal segment. This peculiarity results in the body supports of the caterpillar being confined to the two ends, the three pairs of true legs, situated on the three segments immediately behind the head, supporting the front end, and the one pair of abdominal legs, together with the claspers at the extreme end of the body, supporting the hind end. This peculiar conformation gives rise to a characteristic mode of progression which distinguishes this type of caterpillar. The hind end of the body is drawn forward until the hind legs almost touch the hindermost of the front legs. This results in the body forming a loop in a vertical plane. The purchase is then transferred from the front to the hind legs, and the body stretched forward as far as it will go. A grip is then taken with the front legs, the hind end of the body drawn up as before, and so on. This peculiar and characteristic mode of progression has given rise to the popular name of "looper" caterpillars, and enables an observer to distinguish the insect at a glance. Entomologists refer to the members of the group as Geometers, a name formed from two Greek words meaning "earth-measurers".

It will possibly be a matter of surprise to many tea planters to learn that early records of tea contain no reference to looper caterpillar. It was not, in fact, until 1890 that it seems to have

aroused notice anywhere. E. C. Cotes' book on "Insects and "Mites which attack the Tea Plant in India", published in 1895, refers to a looper caterpillar (species unknown) sent to him from Nowgong in July, 1890. Dr. (Sir George) Watt, in "The Pests "and Blights of the Tea Plant", refers to three species found in Upper and Middle Assam, neither apparently being common. Two species, referred to as (A) and (B) respectively, are unidentified, though (B) was apparently the common Looper. The third species was identified as *Euschema militaris* Linn. In "Indian "Museum Notes", Vol. V, 1902, is a further short reference to an unidentified looper caterpillar from Assam, and in 1903, in the second edition of Watt's "The Pests and Blights of the Tea "Plant", revised by Dr. Harold Mann, appears the first account of the common looper caterpillar under its scientific name of *Biston suppressaria,* Guen.

This short account of the history of the onset of looper as a tea pest is of distinct interest, though the significance of it may not be obvious at first sight. Its significance lies in the fact that looper has come to the fore as a pest of tea since the introduction of the custom of planting shade trees among the bushes. As will be seen later, in the light of our present knowledge this can now be explained, for whereas occasional deposition of eggs on the tea bush may occur, the usual habit of the insect is to deposit the eggs on trees, and in the ordinary way areas devoid of high trees are never likely to suffer from severe infestation.

Of eight * different kinds of looper caterpillar which occur on tea in North East India, only one, *Biston suppressaria,* has ever reached the status of a pest, and it is that insect which is referred to by the tea planter when he speaks of "looper", and which is referred to in the following notes.

---

* *Biston suppressaria* Guen.
Biston bengaliaria Guen.
Boarmia selenaria Hubn.
Boarmia acaciaria Boisd.
Medasina strixaria Guen.
Erebomorpha fulgurita Wlk.
Abraxas sylvata Scop.
Euschema militaris Linn.

An account of the life history of this insect was first given by C. B. Antram in Part I, of this Journal for 1911. This account was, however, neither complete nor entirely accurate.

The female moth deposits eggs which are remarkably small for the size of the insect. These eggs are roughly cylindrical in shape, with the ends convexly rounded, the average size being three-quarters of a millimetre in length and half a millimetre in diameter. The eggs are a peculiar bluish-green in colour with a whitish bloom when fresh and with a smooth shell. They are deposited, as a rule, in irregular clusters, though we have had cases in which the female has deposited a few eggs singly before depositing a cluster. The eggs in a cluster are fastened together by very fine silk strands and at first sight often appear to be stuck together. This, however, is never the case. The cluster of eggs is also covered in an irregular manner with hairs and scales from the female moth. At the upper end of each cylindrical egg is a circular cap, which is pushed open by the insect when emerging and generally remains hinged to the shell at one side. Before the caterpillar emerges the egg darkens in colour and turns brownish, and after hatching the shell is seen to be colourless and translucent. The number of eggs deposited in a cluster varies considerably, but is generally between 200 and 400. Many clusters contain less, others more, and a cluster laid by one female was found to contain as many as 622 eggs. The greatest number of eggs laid by one female in captivity has been 886, in two clusters. One female may deposit more than one cluster. Three is the highest number of clusters so far observed to be deposited by one female, but this is of quite frequent occurrence. The eggs are deposited within a few days after the emergence of the moth. Copulation between the adults may occur on the day of emergence or on the next day, seldom, if ever, later, and never later in captivity. The eggs are deposited on either the second or third day after copulation. The male, as a rule, dies within two days after copulation, the female within two days after egg-laying. In both cases the period may occasionally extend to four days. Egg-laying may go on for two days, but has not been found to go on

longer. Copulation has not been observed to occur more than once.

The situation of the eggs has been a matter of considerable observation. Antram says "The eggs are laid in the bushes "generally on the stems..... . As a result of the "habit of the moths of resting on tree trunks, eggs are also laid "in large numbers in the crevices of the bark, etc." We have found that in the small breeding cages the moths deposited the eggs on leaves, or on flat pieces of paper, quite readily, but when liberated in large cages containing a tea bush the moths have invariably refused to deposit eggs on the bush, even though it had been allowed to grow up to more than seven feet high. In all cases the eggs have been deposited on the wire of the cage at the highest point, the moths having obviously persisted in their attempts to get higher until the last moment. We were therefore forced to the conclusion that deposition of eggs on the tea-bush is exceptional, on the shade trees the rule. That this is so is confirmed by a recent observation by Mr. Gee, of Hautley, who, driving in a car through the estate, noticed that the windscreen was becoming covered with tiny caterpillars. On inspection he discovered that swarms of tiny loopers were letting themselves down from the shade trees on silken threads—and there was a subsequent serious attack of looper on the area. These observations, coupled with the known fact that looper did not attract notice until after the introduction of the practice of planting shade trees in the tea, make it certain that under normal conditions the egg sites are situated on the shade trees, and that the caterpillars let themselves down thence on to the tea. It may be mentioned that as the moths are nocturnal in habit, both copulation and egg-laying take place between dusk and early morning. The eggs hatch, as a rule, in from 8 to 9 days, occasionally taking as long as 12 or 13 days.

As might be expected, the insect which emerges from such a small egg is very very tiny, and is, in fact, only a millimeter and a half in length. Taking into consideration the fact that the full-grown looper caterpillar is by far the largest of our serious

pests, the small size of the initial stages is worthy of note. There is considerable food for reflection in the thought that the resources of Nature are such that from a tiny egg, so small that it must be placed beneath a microscope before even its shape can be ascertained, can emerge an insect which is immediately capable of spinning for itself a cable from 20 to 30 feet long, by which it can let itself down to the bushes beneath, and yet after that effort retains sufficient vitality to engage in an immediate hunt for food. That is what happens when the looper first emerges from the egg. Many caterpillars, when they emerge from the egg, fortify themselves against possible contingencies by first making a meal of the empty shells. Not so the looper. The phenomenon just described generally takes place during the night, and is therefore seldom observed, and in passing it might be well to note that the looper, in all stages, is mainly nocturnal in habit. Many an all-night vigil, in fact, has gone to the compiling of these observations. At this stage the colour of the insect differs from that in the other stages. In later stages, as will be seen, the insect is protectively coloured. In this stage its small size is sufficient protection. It is very dark brown, almost black, with greenish-white lines along the back and sides, and a brownish head. It is too small to bite pieces out of the leaf, and its depredations are confined to feeding on the epidermis of the leaf, never biting right through. Such is the state of affairs in the initial stages of an attack by looper. The bushes are full of young caterpillars unable even to proclaim their presence by biting a hole in the leaf; which feed at night, and hide inside the bushes in the day-time; and average not more than $\frac{1}{15}$ of an inch in length.

The first stage lasts, as a rule, for 5 days, though it may take as long as 7, when the caterpillar moults, and the second stage appears. With this stage cryptic colouration commences, and we find that the insect has changed in colour to a light green, with the head and hindermost segment somewhat more yellow. In this stage the insect attains a length of about 5 m.m., and is now large enough to bite pieces from the edge of the leaf, though its depredations are confined to giving the edge of the leaf an irregular

shape, rather than to biting noticeable chunks out of it. When at rest in the day-time, the insect grips the leaf with his hind-legs and claspers, and sticks out or hangs from the leaf for all the world like a hair attached to it.

The second stage lasts for from 4 to 6 days, occasionally as long as 7, and then a second moult occurs. The insect has now increased to 15 millimetres in length (over half an inch), is a slightly darker green, with the head brown and the hindermost segment a lighter brown. It now begins to make noticeable incisions on the sides of the leaves, though not, as yet, forcing them upon one's notice. This stage lasts for 4 to 5 days, though it may last for as long as 7 days, after which there is another moult, and the insect enters upon the fourth stage. In this stage the caterpillar is beginning to bear a distinct resemblance to the full-grown looper as we all know it. It is still green but with a brownish tinge approximating to the colour of a hardening shoot. The head and the hindmost end, with feet and claspers, are definitely brown, and the insect has attained a length of more than an inch, being some 27 millimetres in length. This seems to be the place to draw attention to a noticeable peculiarity of the head end of the insect. It appears to be truncated, almost as if it had been pinched off, and bears a great resemblance to the pinched brown end of a plucked shoot. Thus, when the caterpillar sits, during the day, perfectly motionless, clasping the shoot with its hind legs and claspers, the rest of the body extended at an angle to the shoot, it looks for all the world like a plucked shoot itself.

After a period varying from 4 to 6 days (generally 4 days) there is yet another moult, and the final stage of the caterpillar existence is reached. The caterpillar has now attained the brownish-grey-green colour of a hardened tea-shoot, and, when at rest, is hard to distinguish from the same. After the moult it is a little over two inches long, but, in this stage, increases in length to two and a half or even three inches. The insect now eats away at a leaf, eating down from the edge to the midrib, until it is eaten completely away, and it is generally in this stage that

the tea planter becomes cognisant of the fact that the insect is present in numbers in the tea.

The time spent in the final caterpillar stage varies considerably, from 7 to 20 days. The cause of this variation it is difficult to ascertain, since caterpillars kept under identical conditions and given leaf from the same bush may show these differences. It may be one of those adaptations, so common in Nature, for making sure that some individuals shall strike favourable conditions.

When full-grown, the caterpillar makes its way to the ground, works its way in to a depth of about two inches, and there turns into a pupa, or chrysalis. No cocoon is found. The chrysalis is just over an inch long, smooth and shining, and varies in colour from brown to jet black. It is very difficult to describe. An illustration of it has already been given in the plate accompanying the article "On Caterpillar Control by Collection of Chrysalides" in Part IV of this Journal for 1921. It can be readily distinguished by the presence of the two spiny ridges, one on each side, at the head end.

The time spent in the pupal stage varies with the time of year. During the season the average duration of this stage is 20 to 22 days, but during the cold weather it averages 107 to 113 days—more than 3 months.

The moths are of a little more than medium size, having a wing expanse of from 2½ to 3 inches. The larger specimens are generally the females, which can also be distinguished from the males by the fact that the body is broader and larger, and more blunt at the end, while the antennæ are not feathery, as they are in the male. The general colour is a dirty grey, with more or less broken black markings. The head, the collar behind the head, the tips of the bunches of hair on the thorax, and the hind end of the abdomen are dull orange-yellow, and there are indeterminate wavy yellowish bands crossing both fore and hind wings. There is considerable variation between individuals, and the distinguishing characteristics that identify the moth to the planter are the size and the fact that the colour is such that as the moth

sits on the trunk of a shade tree, as is its habit during the daytime, it bears an exact resemblance to a patch of lichen. As has already been stated, copulation takes place on the day of emergence, or at latest the day after, and the life-cycle recommences.

Antram stated that there are three broods of looper caterpillar in a year, but we now know that there are four. The following synopsis taken from one of our breeding files is typical of the succession of generations throughout the year.

Full-grown caterpillars were collected from the tea on	October 2nd.
These pupated between	October 3rd. & ,, 29th.
Moths emerged between	March 4th. & March 16th.
The first eggs were laid on	,, 12th.
The first eggs hatched on	,, 26th.
The caterpillars pupated between ...	April 30th. & May 16th.
Moths emerged between	May 23rd. & June 3rd.
The first eggs were laid on	May 29th.
The first eggs hatched on	June 7th.
The caterpillars pupated between ...	July 5th. & July 12th.
Moths emerged between	,, 24th. & August 5th.
The first eggs were laid on	July 29th.
The first eggs hatched on	August 8th.
The caterpillars pupated between ...	Sept. 4th. & Sept. 18th.
Moths emerged between	,, 24th. & October 6th.
The first eggs were laid on	September 27th.
The first eggs hatched on	October 9th.
The caterpillars pupated between ...	Nov. 17th. & Nov. 20th.
Moths emerged between	March 4th & March 13th.

Thus there are four broods of caterpillars during the season, the first occurring in April, the second in June, the third in August, the fourth in October, roughly speaking.

The duration of the different stages, during the season, is remarkably constant in the several generations, and may be tabulated as follows :—

Time from emergence of moth to deposition of eggs	...	3	to	4 days.
Time for eggs to hatch	...	8	to	9 ,,
Time in first caterpillar stage	...	5	to	7 ,,
,, ,, second ,, ,,	...	4	to	6 ,,
,, ,, third ,, ,,	...	4	to	5 ,,
,, ,, fourth ,, ,,	...	4	to	6 ,,
,, ,, fifth ,, ,,	...	7	to	20 ,,
,, ,, pupal stage	...	20	to	22 ,,

Thus the possible variation in the time taken for one complete life cycle is from 55 to 99 days, but as a rule the life cycle is found to take two months, the extremes of variation being rarely met with. In the case of the last generation of the season, which enters into pupation in November, the pupal period is prolonged throughout the cold weather until March, a period of a little over three months.

The above account of the life-history of the looper may be examined with a view to the suggestion of methods of control. Control might obviously be exerted by removal of shade trees, thus causing the moths to fly back to the jungle to lay their eggs. This is entirely unnecessary, as it happens, although it is obviously impossible to deal with the eggs laid on the trees. From the account of the behaviour of the insect in the caterpillar stages it will also be seen that it is extremely unlikely that any tea-planter will realise that the insect is present in the tea in numbers until development is so far advanced that the value of any measures directed against the caterpillar can be but small. If it be a case of sending to Calcutta for insecticides, in fact, the insects will probably have pupated in the soil before the insecticide arrives. There is, however, the fact that the planter knows (now) that when his attack of looper seems to have disappeared the insects are all in the chrysalis or pupal stage, in the soil, and if he can

then put in a hoe he can destroy large numbers. The hoe acts in three ways. It directly destroys many; it turns up others for birds, ants, etc., to destroy; last but not least the pupa is firmly embedded in the soil; it has to be, so that the pupa, which has only a limited power of movement, can wriggle towards the surface to permit of the emergence of the moth. When the soil is loosened the pupa can get no hold—and no forrarder. Thus, a hoe, put in when the caterpillars have disappeared, is indicated as an easy and valuable method of control. Further, however, there is the fact that the pupa remains quiescent in the soil from November to March. It has been proved, as a result of many years experience, that the systematic collection and destruction of chrysalids during the cold weather is a full and sufficient means of control of looper caterpillar, if done regularly every cold weather, and if due attention be paid to this there need never be any complaints of damage by looper.

THE GREYING OF TEA

BY

S. F. Benton.

When investigating a purely physical change in a substance, such as takes place in the development of greyness in tea, direct microscopical examination is of great value. At a magnification of 100-200 diameters green leaf presents a relatively smooth dull surface. During rolling this surface is broken to a small extent, but on the whole retains its evenness although the leaf becomes twisted and folded. At the same time, juice is forced out of the cells in the leaf and stem under the pressure of the roll, and is deposited as a thin film over the surface of the material.

When drying takes place, a general contraction of the leaf occurs, and the whole surface buckles as the moisture evaporates. The tea juice on the outer surfaces dries to an even coating and the leaf turns black. Without this surface coating, the black leaf would absorb the greater part of any light falling on its surface, and the finished tea would have the intensely black appearance of soot.

If, however, carefully manufactured leaf is examined under the microscope, it is seen that the outer layer of dried juice has a shiny appearance, and in consequence any light falling on the leaf is partly absorbed and partly reflected. The question as to whether a particular ray of light will be absorbed or reflected is determined by the angle at which the ray strikes the leaf, but since the surface of the leaf consists of a large number of minute elevations and depressions, the amount of light reflected is roughly the same whatever its angle of incidence. Since the wrinkles caused by drying are too small to be distinguished by the naked eye, the result is the even dull metallic sheen as seen in teas which have not been subjected to rough treatment.

In a normal tea, then, only a small percentage of the total area of the leaf reflects light in any direction. If however, by any means the reflection is increased, the leaf will appear lighter

in colour, and the greater the reflection, the more evident will be the greyness of the leaf.

A microscopic examination of a "grey" tea shows that this increased reflection has been secured, and one or more of three separate factors is almost invariably concerned.

Greying during Cutting.

The majority of grey teas are produced after firing. Such teas under the microscope reveal that the normal wrinkled, shiny surface has become covered with minute yellow "crumbs", consisting of particles of dried juice which have been scored from the smooth coating of juice. The presence of these particles with their irregular outline and many facets creates a great increase in the total amount of light reflected, but since the particles themselves are too small to be distinguished by the naked eye, the combined effect of the black leaf and the light coloured crumbs is an even grey.

In theory, if the leaf be so treated that the detached particles are again fused on to the smooth surface, the greyness should disappear. In practise it has been found that this can be effected by exposure to steam for a few seconds, when the free particles appear to dissolve in the condensed steam. The immediate transformation of a grey tea to one of jet black appearance is striking.

Greyness of this type can be produced by any treatment which subjects the dry leaf to surface abrasion. When leaf is dropped from the firing machines, the surface coating of juice is very brittle, and if cutting and sorting are carried out immediately, a grey tea is the almost certain result. This practise is, however, seldom met with, and since the dried juice on the outside of the leaf rapidly picks up moisture, only ill-treatment in the subsequent processes can produce seriously greyed leaf.

Abrasion takes place when the dry leaf is caused to move against a rough or sharp surface, but it is not always realised that the corners and fractured ends of the leaf itself are sufficiently sharp to cut into the surface of neighbouring leaves; if a moving

mass of leaf is allowed to accumulate at any place during cutting and sorting this effect may become apparent.

Thus when cutting tea ideally, each leaf should fall into a cell, break into two approximately equal parts, and fall out of the machine without further delay. If big leaf is fed into small cells, each leaf will have to be cut several times before the whole of it can leave the hopper. Since the construction of the machine induces a "churning" movement of the material in the hopper, the friction between neighbouring particles of leaf is considerable, and if needlessly prolonged, may cause serious abrasion of the surface. So also, bluntness of the cutting edges reduces the outturn and subjects the leaf to prolonged rotation in the hopper. A phase of the same effect occurs when cutters are run at too high a speed, the leaf not being allowed sufficient time to fall into the cells for cutting. Excessive overloading of the machine will increase the greying effect.

Greying during sorting.

In sorting, both the rubbing together of neighbouring pieces of leaf, and the abrasion of leaf on the wires of the machine have to be taken into consideration. It is frequently stated that galvanised wire greys tea more than does brass wire. This statement requires some qualification, since brass wire is softer and the mesh has a greater tendency towards sagging. While a sagging panel in a "googie" sorter may be of little importance, in the case of a rotary machine of the "Moore" type, a sagging tray causes an accumulation of leaf on the wire, and since any particle of leaf may remain in the depression for several minutes, the consequent prolonged rubbing against the mesh and against other leaf fragments frequently produces grey teas. Overloading of this type of machine may also effect greyness since it encourages friction between neighbouring pieces of leaf.

The speed of the "googie" pattern sorter is probably the most important factor in avoiding surface abrasion. When machines of this type are run at insufficient speed, the leaf is carried upon the mesh for a short distance only, and then rolls

back to the bottom of the cage, considerable friction with the wire being set up. At correct speeds the leaf is held on to the mesh by centrifugal force, and is carried up to almost the highest point of travel, whence it falls directly to the bottom of the cage without contact with the mesh. At excessive speeds, the leaf is carried round the full circle and sorting is not effected.

In general, then, any condition which subjects the leaf to prolonged rubbing either against rough metal or against neighbouring fragments of leaf will roughen the smooth surface of the leaf and produce the scattering of light which gives the effect of greyness.

Greying before cutting and sorting.

It is occasionally found that tea drops from the firing machine with a dull "bloom" instead of the customary velvety black colour. Increased reflection of light is again responsible although the defect has a different origin. One can usually associate this type of greyness with the manufacture of "tippy" teas. The bud in such teas bears a large number of fine, silvery hairs which, during rolling, become coated with tea juice. Fermentation develops a golden yellow colour in this juice and on firing the hairs become gummed together into a compact mass with the characteristic golden appearence of bright tip.

During rolling some of these hairs are detached from the bud and are deposited indiscriminately over the larger leaves. Furthermore, the hairs are not entirely confined to the bud, but occur in a dispersed state over the lower surface of the first leaf and to a lesser extent on the mid-rib of the second leaf. When fired, the hairs on the coarse leaf are insufficient in number to give a golden appearance, but cause a considerable increase in reflection of light, and consequently a dull bloom is produced.

It is obviously impossible to eliminate this type of "greyness" completely owing to the natural presence of a few hairs on the larger leaves, but if such an appearance coincides with a poor coloured tip, a defect in manufacture is indicated, *i.e.*, the hairs

on the bud are being torn off during rolling and distributed throughout the bulk of the leaf.

The amount of tip lost in this way, and the corresponding increase in the "bloom", will depend on conditions of rolling and withering. Fast rolling with any state of wither is liable to destroy tip. The optimum speed for the first roll is still open to question but it seems probable that 55 r. p.m., is suitable. At this speed, little of this type of greying should occur with a good wither, and it is possible to apply some pressure when the wither is on the high side.

Expanding the same principles, it will be realised that if insufficient fine leaf is removed after the first roll, a certain percentage of the buds will receive heavy rolling in the second stage, and this may lead to "greying" of the leaf and to loss of tip in the second fine mal. In short, a condition which exposes the fine hairs on the bud to a strong shearing action is liable to produce greyness of this type.

Greyness developed during firing.

Under the present system of low temperature firing, the third type of greyness is rarely seen. During the roll, only a small proportion of the juice is expressed, the major portion remaining inside the cells of the leaf and stem. If this leaf is exposed in the firing machine to a blast of dry air at a high temperature, the outer surface is dried almost immediately, and obstructs the passage of moisture from the inner parts of the leaf. Under the influence of the increasing temperature as the tea passes through the machine, the internal water may be raised to the boiling point, so that steam is produced, and the sudden increase in pressure within the leaf raises a crop of blisters.

If the expansion takes place in the inner portions of the leaf, large blisters, visible to the naked eye, may be produced, but if the individual "epidermal" cells, which form the outer casing of the leaf burst, the blisters are exceedingly small and are only to be seen under the microscope.

It requires very little friction during the subsequent processes of cutting and sorting to break the tops of these minute blisters, and when this occurs, an increased reflection of light is again set up, with a consequent grey appearance.

A modification of this effect is seen when the production of steam is not sufficient to cause actual blistering but results in slight separation of the whole layer of epidermal cells from the main tissues of the leaf. The air space between the two tissues may then serve to reflect light which would otherwise be absorbed.

However the adoption of inlet temperatures not exceeding 212°F., coupled with exhaust temperatures in the region of 120°F., for the first stage of firing, has resulted in a more even loss of moisture from the leaf, and in consequence, blistering is seldom seen under present conditions.

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The whole question of greyness in teas is thus seen to be intimately connected with the reflection of light from the surface of the leaf, and a rough microscopical examination of the leaf is usually sufficient to indicate the nature of the defect. The type of greyness having been established, the detection of its origin should present little difficulty.

A rotting stump with a few miserable shoots ; the central tissues of the bush are more decayed than those more directly connected with the bark.

HEAVY PRUNING AND STEM DISEASE

BY

A. C. TUNSTALL.

It is quite safe to remark that deterioration of a plot of tea is always associated with severe stem disease. The stem disease in question is not however the result of infection by a specific organism. It is the effect rather than the cause of the condition of the plant. For some years the mycological aspect of the problem has been receiving close attention but it will require some years more before it will be possible to draw conclusions based on adequate scientific proof. In the meantime sufficient progress has been made to allow tentative suggestions to be put forward. It is however probable that these suggestions will require some revision in the light of further observations.

In every tea district, on almost every garden, there are areas of tea which are annually becoming less productive. Examination of the soil frequently reveals nothing to account for the deterioration and in many cases when such areas are replanted the new bushes grow normally. Soil deficiency cannot be the cause of the deterioration of this tea. It must be something which is happening to the plants themselves.

If one of the deteriorating plants be dug up and examined critically it will be found, generally, that the roots are in good condition but that the stems and branches are full of rotting holes. If the progress of such bushes be watched for a number of years it will be found that branch after branch drops off. In the early years new growth arises from the collar but eventually this growth becomes involved and all that is left is a rotting stump with a few miserable shoots (see Plate 1). On most of the older tea gardens all the various stages of such deterioration may be found. In most cases it will be noticed that the process was obviously accelerated when the bushes concerned were heavy pruned. Examination of crop records of the various sections generally shows that the maximum yield of a section before it was heavy pruned is not usually approached in the subsequent years. The practical

planter sees the fructifications of fungi on the rotting stems and naturally asks what the Mycological Department is doing in the matter. Mycological examination shows that the fungi which are associated with the rot are those which commonly attack dead wood and are incapable of attacking vigorous living tissues. It must be assumed therefore that the tissues were already dead or at any rate moribund before they were attacked by these fungi. Further it may be asked why these very common fungi did not seriously damage the plants before they were heavy pruned. They were always present and had ample opportunity of entering the plant through the numerous pruning cuts. In fact they do attack the dead wood on the pruning cuts and yet make no serious progress until after heavy pruning. It would seem therefore that the trouble was more directly associated with pruning than with fungal infection. There are however bushes here and there which are dying in a similar manner without having been heavy pruned. In such cases the rotting branches can generally be traced to dead snags. These are usually situated in the centres of the bushes concerned. It may be safely assumed from our knowledge of the fungi concerned that the snags were dead or moribund before they were attacked by the fungi. The most important part of the problem is to find out why certain branches die back. Mycological examination of such branches proves that they frequently die before any organism attacks them. It is necessary therefore to go beyond the purely mycological standpoint.

The metabolism of green plants in general and the tea plant in particular has been discussed in this journal and in lectures a number of times but it is necessary to refer to it again in order to make what follows quite clear.

The tea plant in common with other green plants obtains the energy for its growth from sunlight through the agency of the leaves. From the soil, through the roots, the plant absorbs water in which simple compounds of nitrogen, potash and phosphoric acid etc., are present in very dilute solution. The water containing these substances is transported to the leaves. Through the leaves the bulk of the water escapes into the air in the form

of vapour. Some of the water is retained and combined with carbon dioxide through the agency of light to form carbohydrates. When these substances are broken down again into carbon dioxide and water the energy used in holding them together is made available for the construction of other compounds. The surplus carbohydrates are stored up principally in the form of starch. Without the energy obtained from light by the leaves no growth can take place. In the absence of leaves no new growth can be formed, unless sufficient reserve of energy has been stored up in the form of carbohydrates. When all the leaves have been removed from a plant the new growth is entirely dependent on the reserves. It is obvious therefore that in the absence of adequate reserves satisfactory new growth cannot be produced on plants which have been deprived of their energy absorbing organs. Successful regeneration of a green plant after severe pruning must of necessity depend on the amount of reserves present in the remaining tissues.

Fluctuations in starch reserves.

Before any real progress could be made with the problem of stem disease it was essential to find out more detailed information about the metabolism of the unpruned and unplucked tea plant. With this object in view observations have been carried out on seed trees, on unpruned and unplucked seed trees. The observations indicate that the production of new growth coincided with a reduction in the amount of starch stored in the roots. The deficiency was made up when the new leaf had matured. On plucked and pruned bushes also it was found that there was a distinct reduction in the starch reserves during the period of rapid growth following the pruning. This starch was replaced as the new growth matured. In each succeeding flush the starch fluctuated similarly, *i.e.*, it was reduced during the period of rapid growth and reaccumulated during periods of slower growth. In the tea plant it was noticed that there is comparatively little starch stored in the stems but in the roots there may be as much as 25% of the total dry weight. The details of this investigation will be published later when our observations have been repeated for another year.

When a tea plant is pruned many buds which would normally have remained dormant begin active growth. On an unplucked tree most of the new growth occurs in the axils of leaves and the leaves concerned help to supply energy to the young growth. In spite of this help the drop in starch reserves in the roots during the period of active growth is still noticeable. It will be readily understood that in the case of pruning, when most of the leaves have been removed and dormant buds are stimulated to grow, the call on the reserves is much greater.

The cause of the dying back of branches.

Before the reduction of starch in the roots is noticeable, that in the branches has already disappeared. There is a direct transference of food substances from one branch to another and it is possible for one branch to grow at the expense of its neighbours. New growth comes away most readily from the younger wood and in the absence of ample reserves the older wood may be drawn upon to such an extent to support the growth on the younger wood that the former dies back.

When the bushes are collar pruned or very severely cut back it is the custom in some districts to leave a single branch unpruned until the new growth commences. When the bushes are deficient in reserve starch the leaves on the unpruned branch, by continuing to augment the supply during the period in which the new growth is drawing on the reserves, may certainly be useful. When an unpruned branch has been left it should be pruned as soon as the new growth on the remainder of the bush has become established.

When a bush is cut back to old hard wood a certain amount of dying back appears to be inevitable. It can be reduced by the use of bark softening solutions, such as, strong lime sulphur solution, provided the bush is well stocked with reserves. If however, the bush concerned is in poor condition, although the softening of the bark on the older branches enables them to come away almost as quickly as the younger ones, the new growth on the former will die back on account of the absence of the reserves

PLATE 2.

Cross sections of tea roots showing different amount of starch stained black with iodine.

A root of average thickness for iodine test is shown below.

necessary to sustain it until it is able to maintain itself. Unless the bush concerned be well supplied with reserves at the time of pruning some dying back will certainly take place. No paint, spray fluid or other patent medicine will overcome the difficulty.

Ascertaining the amount of starch reserves in tea roots.

Before any form of heavy pruning is undertaken it is desirable that the roots should be examined to ascertain whether the starch content is sufficient. It is possible to do this in a very simple manner. A number of representative bushes should be selected and a single lateral healthy root, about the thickness of the little finger, should be removed from each. This can be done without causing serious damage to the bushes concerned. The cut end of the piece of root removed should be cut square across and smoothed with a sharp knife. The surface of the cut should then be wetted with a weak solution of iodine. The exact strength is immaterial. The following is used at Tocklai. Dissolve 1 gram of potassium iodide in 100 c.c. of water and add 0.3 gram of iodine crystals. It is advisable to carry out this test after plucking has ceased *i.e.*, in December or January as the amount of reserves are then at their maximum.

The starch in the cells is stained black by the iodine and it is easy to obtain a rough estimate of the quantity present. When the root is well filled with starch the whole area of the exposed wood appears black when treated with iodine. The accompanying photographs (Plate 2) make this clear. If the starch content is low it is advisable to postpone the pruning until the amount of reserve starch has been built up. As the production of starch primarily depends on the leaves, one of the best ways of helping the bushes to accumulate it is by removing less leaf.

Cutting back or collar pruning young plants.

Before leaving this aspect of pruning special reference should be made to the heavy pruning of vigorous young plants. Periodical observation of the amount of starch in the roots of such plants shows that it fluctuates more than is the case with larger ones.

This may reasonably be expected as the amount of storage space in the root of a young plant relative to the amount of new growth is smaller than is the case in an older plant. It is therefore important to choose a time for pruning when the reserves are at their maximum. On this account heavy pruning should not be carried out during the period of vigorous growth. It is better to wait until new growth has temporarily ceased. This does not mean that the heavy pruning of young plants must only be done in the cold weather. Observation of unplucked plants shows that they grow vigorously for a period and then go banji for a period. If the roots of a few plants are examined for starch by the method described above, it will be found that the starch reserves are lower at the end of a period of vigorous growth and accumulate again during the succeeding lull in growth. By choosing the time carefully it is possible to avoid pruning the plants when the reserves are low. For instance, the period preceding the break of the rains is usually a time of slow growth. By pruning the plants just before the vigorous growing period which follows the break of the rains advantage is taken of the accumulation of reserves in the preceding period. The writer has seen healthy vigorous plants fail to survive when collar pruned during a period of vigorous growth. Subsequently examination showed that the reserves had been used up and there was little or nothing left to provide for the new growth following the pruning.

The healing of wounds.

When wounds are made on many kinds of plants the cut surface is rapidly sealed by a substance called wound gum. This is apparently produced from reserve carbohydrates. In the case of the tea plant very little wound gum is produced and the wound remains more or less unprotected until covered over by callus growth. It is possible that the absence of wound gum is associated with the comparatively small amount of starch in the stems of the tea plant. In a tea plant with roots well filled with reserve starch callus growth begins to form almost immediately after a wound has been made, while in the case of plants deficient in starch the visible growth of callus may be delayed for months although new

growth of leaf may proceed at once. It would seem therefore that callus growth is not a first call on the plant's reserves. It does not take place to any great extent until the other requirements of the plant have been provided for. In order for a wound to heal satisfactorily it is necessary for the plant concerned to be in good condition and that sufficient leaf growth be allowed to remain on the bush to provide a surplus of carbohydrates. Our mycological work has shown that all the wounds examined, both painted and unpainted, were more or less infected by fungi but only in a few cases did the fungi concerned make any progress. The fungus may however remain alive in the surface layers of wood even after the callus has completely covered them. In very few cases was it observed that any serious damage had been caused by the fungi after the wound had been completely covered by callus. This does not necessarily indicate that the covering of the wound prevented further progress of the infection. It is more probable that where the bush was sufficiently vigorous to produce the necessary callus it was also in a condition to resist the further invasion of the fungi.

Various conditions which influence the success of heavy pruning.

The internal conditions of the tea bushes are not the only factors concerned with the success or otherwise of heavy pruning. Climatic conditions are also important. Unfortunately these cannot be controlled effectively. Humidity of the air appears to be the most important factor. Any planter with experience of both the Assam Valleys is well aware with the difference in the effects of pruning in the two areas. During the pruning season the cold weather temperatures do not differ greatly but the humidity is very much higher in the Assam Valley than it is in the Surma Valley. Under less humid conditions the new growth does not develop so quickly. This leads to a greater disparity between the time of development of new growth on the old compared with the younger wood and in consequence there is a greater tendency for the dying back of individual branches. This is further emphasized in the exceptionally forcing weather which

usually succeeds the break of the rains. Those branches which have come away early then grow so vigorously that the growth on the remaining ones is frequently suppressed. It is therefore important to plan out the heavy pruning in the Surma Valley and districts with similar climatic conditions with special care. In districts where Blister is likely to occur it is important to take this blight into consideration in fixing the time of heavy pruning. In Upper Assam Blister blight occurs during the latter part of the cold weather. This blight only causes serious damage on tea bearing succulent growth such as heavy pruned or collar pruned tea. By delaying such pruning until the latter part of the cold weather the new growth is not present until the warmer weather renders conditions unsuitable for attacks by this blight. In the Surma Valley Blister blight occurs on some gardens and the same recommendations apply. In Darjeeling, however, Blister blight is most prevalent in June and July and almost entirely absent in the cold weather. In selecting the time for heavy pruning therefore it is necessary to take this into consideration and to leave sufficient time for the new growth to harden before the Blister blight season commences. By attention to these precautions serious damage by Blister blight may be avoided to a great extent.

Preparing bushes for heavy pruning.

Frequently financial and labour considerations make it difficult to carry out such pruning with sufficient care to ensure successful results. When heavy cutting is unavoidable, under all conditions, it is of primary importance for reasons given above that bushes which are not in good condition be prepared before the operation. It is impossible to generalise regarding the methods of preparation. The object of the preparation is to increase the reserves. As the reserves depend upon the action of the leaves it is obvious that more leaf must be left on the bushes. In some cases it is necessary to stimulate leaf production by suitable manuring. Whether it is desirable to leave the bushes unplucked for a whole season depends on circumstances. In Upper Assam there is a tendency for good jat bushes to grow up in the

centres and better results are obtained by plucking at a higher level, say 4 ft., than by leaving them unplucked. On poor hybrid however the bushes have a tendency in all districts to go banji and produce flowers and seed instead of leaf. Leaving such tea unplucked does not benefit the plants so much as plucking lightly throughout the season. In some cases it is sufficient to leave the tea unplucked for the latter half of the season preceding the pruning. It cannot be too greatly emphasized that the leaves are prime essential, for increasing the amount of reserves in the roots. Manuring of the soil is valuable in so far as it increases the leaf area. Mixtures containing readily available nitrogen are specially recommended because they stimulate growth of leaf. The increased growth of leaf may actually do harm to the bush if so much be plucked off that insufficient leaf area is left to replace the reserves used in the production of the new shoots and to provide in addition a surplus for accumulation as reserves. The amount of growth it is necessary to leave before plucking commences on normally healthy tea bushes depends on local conditions.

Having got the bushes into a vigorous condition, they may be cut across at the required height and obviously rotten wood cut right out. Special care need not be taken in regard to spacing, cleaning up cuts etc., at this time. In the succeeding growing season ample growth should be allowed in order to ensure good pruning wood in one season. In the following cold weather the bushes should be pruned again, all dead and moribund wood should be removed and the cuts carefully cleaned up. During the two seasons involved in this operation all bushes which are badly rotted or which fail to come away satisfactorily should be removed and replaced. Experience has shown that it is waste of time and money to attempt to renovate bushes in which the main stem is badly rotted below the collar.

In the absence of the precautions outlined above any attempt to prevent stem disease by application of fungicides or wound paints is futile.

Fungi associated with dead branches.

Even when the pruning has been carried out with the greatest care and foresight a certain amount of stem disease may be found on any section of tea. Any exposed wound is liable to infection by micro-organisms. The investigation of the micro-organisms concerned has been carried on for some years but is still far from complete. It is however possible to draw some inferences. The commonest fungi found in rotting wounds are those usually found attacking dead wood in the neighbouring jungles. Although it is possible that these fungi may attack dead wood which has not been previously infected by other micro-organisms they do not appear to attack living tissues even when the latter adjoin dead ones. Other fungi apparently kill the tissues in advance of the rot producing ones. These fungi do not rot the tissues. The fungi in question belong to the Ascomycetes while the most of the rot producing ones belong to the Basidiomycetes. Most of the cuts on a pruned tea bush become infected but when the cut is surrounded by actively growing tissues the infection does not usually proceed very far below the surface and no appreciable damage is done. But when a branch is weakened for the physiological causes outlined above infection proceeds with greater rapidity and eventually a rotting hole may form. By cutting off such a branch before infection has reached the main stem permanent damage is avoided. It is certainly possible to prevent infection of wounds temporarily by spraying with lime sulphur solution immediately after pruning. This temporary prevention is of considerable value as it frequently keeps off the fungus until the surface of the wound has dried up. When the surface cells have dried up they are less susceptible to infection. This delay in infection is important as it affords a chance for active growth to commence before the fungus becomes established. If active growth in the neighbourhood of the wound does not take place no treatment will prevent infection permanently.

By using very concentrated lime sulphur solution not only is the infection of wounds temporarily checked but the bark is softened also. The concentrated solution made according to the

I.T.A. formula (*i.e.*, about 8° Beaume) is strong enough. Stronger concentrates may be diluted according to their strength. This application should be made immediately after pruning and should not be allowed to come into contact with buds or green shoots as it will burn them.

Wound paints.

Our experiments on the treatment of wounds by various paints though not complete have yielded some interesting results. It has been found that in the case of both coal tar and resin varnish applied to collar pruning cuts on seedlings 1 inch to 1½ inch in diameter the degree of infection was distinctly greater than that on untreated cuts. This was probably due to the retention of moisture in the tissues beneath the impervious layer. The unpainted cuts dried more rapidly and thus afforded less suitable conditions for infection. It would seem therefore that an antiseptic is a necessary part of such paints but the antiseptic substance should not be such that damage is caused to the living tissues of the tea plant.

Experiments are now in progress with a bitumenous paint in which is incorporated a mild antiseptic. It is however too early to ascertain the results. Such paints have been found very successful in treating rubber trees and certainly cause no damage to the tea plant. Bordeaux and Burgundy mixtures successfully prevent infection but in many cases check the growth of callus. They are therefore no longer advocated. Another treatment for large wounds has been tried with some success. This consists of paste of cowdung, mud and sulphur: the sulphur being in a concentration of about 10% by volume. Callus grows very rapidly under this paste but the growth is so thick on large wounds that a deep pit is formed in the centre of the wound by the rim of callus. As this is undrained rot eventually starts there.

Cleaning out branches which are likely to die back.

A great deal of help can be obtained by studying bushes which have been similarly pruned in previous years. It will be at once apparent that certain types of branches have a greater ten-

dency to die back. Such branches may be removed in the first year of the operation. This reduces the amount of work in the following year. It however increases the cost in the first year and it is questionable whether any great advantage is gained as no appreciable reduction in the cost in the second year is afforded.

Branches which arise low down in the centres of the frames are likely to cause conjestion. On this account they should be cut off when they are young. If however they have been allowed to grow into strong branches and their position is such that it is difficult to cut them out flush with main stems, it is better not to cut them back below the general level of the bush. If such branches are cut back too low they will die and form a rotting snag in such a position that it cannot be cleaned out properly. In Plate 3 such a branch is shown, marked A. An outer branch has been removed to make it clear. Such a branch should have been cut out when very young or if that was not done it should not have been cut below the general level. As it was cut back below that level it died and in a year or two there would possibly be a rotting hole in the main stem of the bush concerned. It is very noticeable that the tissues in the centre of a bush (see Plate 1) are more liable to decay than those more directly connected with the bark of the roots. It is therefore desirable to avoid cutting large branches out of the centres of the bushes. It is better to cut them out when they are very small so that a large wound is avoided. A great deal of trouble can be avoided by cleaning out unwanted branches while they are small so that the necessity for making large wounds in dangerous places will be avoided as much as possible. If this be done systematically it should never be necessary to prune the bushes very low. Although it is desirable to cut out young shoots originating in the centres of the frames of bushes it is also very necessary to keep the centre of the plucking surface well filled. The shoots which fill up the centres need not originate in the centre but from the lateral branches. In this connection it is however necessary to note that in the case of young seedlings it is possible to go too far in regard to the removal of unwanted branches. The undue reduction in leaf area occasioned by the

PLATE 3.

Branches (marked A) which should have been removed when they were young or should not have been cut below the general level of the bush.

frequent cutting back of centres while the plants are very young may cause permanent dwarfing.

There are a number of fungi, such as *Nectria cinnabarina*, which attack through pruning cuts in spite of the good condition of the plants concerned but as they are not very widely distributed it is not necessary to take them into account in devising general routine methods.

It is suggested that heavy pruning be carried out as follows.

Before pruning:—

1. Test a number of bushes representative of the section concerned by the iodine test for starch reserves.
2. If the starch is deficient delay pruning until the reserves have been accumulated by resting the bushes etc.
3. Remove any bushes which are very bad and unlikely to respond to further treatment.

Pruning:—

1st year.

1. Cut the bushes across at the required height.
2. Remove and burn the heavy prunings.
3. Paint or spray the bushes with strong lime sulphur solution.
4. Allow ample growth to produce good pruning wood in one season.
5. Dig out and replace all bushes which are badly diseased.

2nd year.

1. Prune out all dead and moribund wood and trim up all wounds very carefully.
2. Spray with dilute lime sulphur solution.

3. Dig out and replace all bushes which have not come away satisfactorily.

4. Allow sufficient growth to ensure satisfactory callus formation.

So far the question of preventing deterioration has been discussed. Unfortunately on most gardens the question of arresting deterioration which has already commenced requires serious attention.

It is certainly possible by careful nursing to renovate moribund bushes. The same principles which apply to the preparation of poor tea for heavy pruning should be followed in devising the treatment of tea which has already deteriorated. It is desirable to discuss the programme for any such renovation with the Scientific Department as each case requires to be considered on its own merits. A few sample bushes should be sent to Tocklai for examination together with full details such as crop records, percentage of vacancies, class of soil etc., etc. It is in many cases doubtful whether renovation is worth the expense and trouble. As a general rule the sections concerned have many vacancies and only a small percentage of the remaining bushes are yielding or likely to yield a really satisfactory crop. Such sections may be recorded in the books as good jat Assam, good jat Burma or good jat something etc., and it is difficult to persuade shareholders that it is more economical to replant than to renovate such sections.

By reference to the results obtained on other sections in the neighbourhood it is possible to make an approximate estimate of the costs and results of renovation compared with those of replanting. The financial aspect would then determine the further procedure. It is unsafe to generalise and each section should be discussed on its merits. It should however be emphasized that whatever treatment be applied to moribund tea bushes it takes time to replace dead branches. The time required to grow new plants may in some cases be less than that required to grow new frames on old plants.